COOLNEWS

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TABLE OF CONTENTS

Stellar Abstracts

Oxygen from the λ7774 High-Excitation Triplet in Open Cluster Dwarfs: Hyades

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Oxygen abundances have been derived from the near-IR, high-excitation λ7774 O I triplet in high-resolution, high signal-to-noise spectra of 45 Hyades dwarfs using standard one dimensional, plane-parallel LTE models. Effective temperatures of the stellar sample range from $4319 - 6301$ K, and the derived relative O abundances as a function of $T_{\rm eff}$f evince a trichotomous morphology. At $T_{\rm eff} > 6100$ K, there is evidence of an increase in the O abundances with increasing $T_{\rm eff}$, consistent with non-LTE (NLTE) predictions. At intermediate $T_{\rm eff}$f ($5450 \leq T_{\rm eff} \leq 6100$ K), the O abundances are flat, and star-to-star values are in good agreement, having a mean value of $[{\rm O/H}] = +0.25 \pm 0.02$; however, systematic errors at the ≤ 0.10 dex level might exist. The O abundances for stars with $T_{\rm eff} \leq 5450$ K show a striking increase with *decreasing* $T_{\rm eff}$, in stark contrast to expectations and canonical NLTE calculations. The cool Hyades triplet results are compared to those recently reported for dwarfs in the Pleiades cluster and the UMa moving group; qualitative differences between the trends observed in these stellar aggregates point to a possible age-related diminution of triplet abundance trends in cool open cluster dwarfs. Correlations with age-related phenomena, i.e., chromospheric activity and photospheric spots, faculae, and/or plages, are investigated. No correlation with Ca II H+K chromospheric activity indicators is observed. Multi-component LTE "toy" models have been constructed in order to simulate photospheric temperature inhomogeneities that could arise from the presence of starspots, and we demonstrate that photospheric spots are a plausible source of the triplet trends among the cool dwarfs.

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Photospheric and Chromospheric Active Regions on Three Single-lined RS CVn Binaries

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A monitoring of three active RS CVn binaries has been performed with medium resolution spectroscopy with the aim of investigating the behavior of chromospheric and photospheric inhomogeneities. Surface temperature, as recovered from line-depth ratios (LDRs), allowed us to map the photospheric spots, while the Hα emission has been used as an indicator of chromospheric inhomogeneities. We have found that the rotational modulation of the Hα emission is always in anti-phase with the temperature wave, i.e. at the time of our observations active regions at chromospheric and photospheric levels are closely spatially associated in these active stars. The residual Hα profiles, obtained as the difference between the observed spectra and non-active templates, are well reproduced by a two Gaussian fitting. The broad emission component, responsible for the wide emission wings in near all the spectra, is often blue-shifted with respect to the center of the stellar disk. The narrow Hα emission displays a phase-dependent variation in all stars and is anti-correlated with the photospheric diagnostics, while the broad one displays no or little rotational modulation. We suggest that the broad emission component is mainly related to physical phenomena, like micro-flaring or strong chromospheric velocity fields, occurring all over the star disk, while the central narrow emission is more affected by chromospheric plages. We have also detected a modulation of the intensity of the HeI D_3 line with the star rotation, suggesting surface features also in the upper chromosphere of these stars.

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Water Vapor on Betelgeuse as Revealed by TEXES High-Resolution 12 μm Spectra

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The outer atmosphere of the M supergiant Betelgeuse is puzzling. Published observations of different kinds have shed light on different aspects of the atmosphere, but no unified picture has emerged. They have shown, for example, evidence of a water envelope (MOLsphere) that in some studies is found to be optically thick in the mid-infrared. In this paper, we present high-resolution, mid-infrared spectra of Betelgeuse recorded with the TEXES spectrograph. The spectra clearly show absorption features of water vapor and OH. We show that a spectrum based on a spherical, hydrostatic model photosphere with $T_{eff} = 3600$ K, an effective temperature often assumed for Betelgeuse, fails to model the observed lines. Furthermore, we show that published MOLspheres scenarios are unable to explain our data. However, we are able to model the observed spectrum reasonably well by adopting a cooler outer photospheric structure corresponding to $T_{mod} = 3250$ K. The success of this model may indicate the observed mid-infrared lines are formed in cool photospheric surface regions. Given the uncertainties of the temperature structure and the likely presence of inhomogeneities, we cannot rule out the possibility that our spectrum could be mostly photospheric, albeit non-classical. Our data put new, strong constraints on atmospheric models of Betelgeuse and we conclude that continued investigation requires consideration of non-classical model photospheres as well as possible effects of a MOLsphere. We show that the mid-infrared water-vapor features have great diagnostic value for the environments of K and M (super-) giant star atmospheres.

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Evidence of the FIP Effect in the Coronae of Late-type Giants

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β Cet, 31 Com and μ Vel represent the main stages through which late-type giants evolve during their lifetime (the Hertzsprung gap (31 Com), the rapid braking zone (μ Vel) and the core helium burning "clump" phase (β Cet)). An analysis of their high resolution *Chandra* X-ray spectra reveals similar coronal characteristics in terms of both temperature structure and element abundances for the more evolved stars (μ Vel and β Cet) with slight differences for the 'younger' giant (31 Com). The coronal temperature structure of 31 Com is significantly hotter showing a clear peak while β Cet and μ Vel show a plateau. β Cet and μ Vel show evidence for a FIP effect in which coronae are depleted in high FIP elements relative to their photospheres by a factor of ~ 2. In contrast, 31 Com is characterized by a lack of FIP effect. In other words, neither depletion nor enhancement relative to stellar photospheric values is found. We conclude that the structural changes during the evolution of late-type giants could be responsible for the observed differences in coronal abundances and temperature structure. In particular, the size of the convection zone coupled with the rotation rate seem obvious choices for playing a key role in determining coronal characteristics.

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X-Ray Spectral Variability During an Outburst in V1118 Ori

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We present results from a multi-wavelength campaign to monitor the 2005 outburst of the low-mass young star V1118 Ori. Although our campaign covers the X-ray, optical, infrared, and radio regimes, we focus in this Letter on the properties of the X-ray emission in V1118 Ori during the first few months after the optical outburst. Chandra and XMM-Newton detected V1118 Ori at three epochs in early 2005. The X-ray flux and luminosity stayed similar within a factor of two, and at the same level as in a pre-outburst observation in 2002. The hydrogen column density showed no evidence for variation from its modest pre-outburst value of $N_{\rm H} \sim 3 \times 10^{21}$ cm^{-2}. However, a spectral change occurred from a dominant hot plasma ($\sim$ 25 MK) in 2002 and in January 2005 to a cooler plasma ($\sim$ 8 MK) in February 2005 and in March 2005. We hypothesize that the hot magnetic loops high in the corona were disrupted by the closing in of the accretion disk due to the increased accretion rate during the outburst, whereas the lower cooler loops were probably less affected and became the dominant coronal component.

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Editor's Note: The above abstract is being cross-listed with the Star Formation Newsletter.

Anomalous X-ray Line Ratios in the cTTS TW Hya

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The cTTS TW Hya has been observed with high-resolution X-ray spectrometers. Previously found high densities inferred from He-like f/i triplets strongly suggested the detected X-ray emission to be dominated by an accretion shock. Because of their radiation field dependence He-like f/i ratios do not provide unambiguous density diagnostics. Here we present additional evidence for high densities from ratios of Fe XVII lines. Key Fe XVII line ratios in TW Hya deviate from theoretical expectations at low densities as well as from the same measurements in a large sample of stellar coronae. However, a quantitative assessment of densities is difficult because of atomic physics uncertainties. In addition, estimates of low optical depth in line ratios sensitive to resonance scattering effects also support a high-density emission scenario in the X-ray emitting regions of cTTS.

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Solar Abstracts

Repetitive Occurrence of Explosive Events at a Coronal Hole Boundary

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SUMER/SoHO data taken at a coronal hole boundary show a repetitive explosive event occurrence rate of around 3 min increasing to over 5 min towards the end of the activity. We suggest that the neighbouring oppositely directed closed and open field lines at the coronal hole boundary undergo repetitive reconnection seen as a sequence of explosive events. The repetitive reconnection may be triggered by transverse oscillations of the flux tubes in the closed field line region. These oscillations periodically separate and bring together the closed and open field lines on the two sides of the coronal hole boundary. An important indicator favouring the interpretation in terms of a kink mode is the observed increase in the oscillation period.

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A Necessary Extension of the Surface Flux Transport Model

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Customary two-dimensional flux transport models for the evolution of the magnetic field at the solar surface do not account for the radial structure and the volume diffusion of the magnetic field. When considering the long-term evolution of magnetic flux, this omission can lead to an unrealistic long-term memory of the system and to the suppression of polar field reversals. In order to avoid such effects, we propose an extension of the flux transport model by a linear decay term derived consistently on the basis of the eigenmodes of the diffusion operator in a spherical shell. A decay rate for each eigenmode of the system is determined and applied to the corresponding surface part of the mode evolved in the flux transport model. The value of the volume diffusivity associated with this decay term can be estimated to be in the range 50–100 $\mathrm{km^2 s^{-1}}$ by considering the reversals of the polar fields in comparison of flux

transport simulations with observations. We show that the decay term prohibits a secular drift of the polar field in the case of cycles of varying strength, like those exhibited by the historical sunspot record.

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Solar Cycle As A Forced And Damped Harmonic Oscillator : Long-term Variations Of The Amplitudes, Frequencies And Phases

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We model the solar activity cycle as a forced and damped harmonic oscillator which consists of two parts, *viz.,* sinusoidal and transient parts. The amplitudes, frequencies, phases and decay factors of such a harmonic oscillator are determined from fitting the equation of sinusoidal and transient parts to the sunspot data for the years 1755-1996 (cycles 1-22) and the results are : (i) there is a long-term decreasing trend in the phase, while the amplitude and the frequency (or period of $\sim 11\,yrs$) of the sinusoidal part remain constant for all the solar cycles, (ii) the amplitude of the transient part is phase locked with the phase of the sinusoidal part , (iii) for all the cycles, the period and decay factor (that is much less than 1) of the transient part remain approximately constant, (iv) except cycles 6 and 15, the phases of the transient part are approximately constant with a magnitude of $\sim \pi/2$ radians and, (v) for the cycles 6 and 15, the simultaneous change in magnitude of phase difference ($\sim 2\pi$ radians) between the transient and sinusoidal parts and of very low sunspot activity may be due to the Maunder minimum type of oscillations.

The constancy of the amplitudes and the frequencies of the sinusoidal part and a very small decay factor from the transient part suggests that the solar activity cycle mainly consists of persistent oscillatory part that might be compatible with long-period ($\sim 22\,yrs$) Alfven oscillations.

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Supergranule Superrotation Identified as a Projection Effect

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Previous measurements of the rotation rate of the supergranule Doppler velocity pattern revealed surprising characteristics: (1) the pattern rotates faster than the plasma at the surface and, at each latitude, it rotates faster than the plasma at any level below the surface (superrotation), (2) larger cells rotate more rapidly than smaller cells, and (3) faster rotation rates are found when using cross-correlation techniques with larger time-lags between Doppler images. We simulate the supergranulation velocity pattern using a spectrum for the cellular flows that matches the observed spectrum but we keep the pattern unchanged and rotating rigidly. Our simulation shows that the superrotation and its dependence upon cell size can be largely reproduced by projection effects on the line-of-sight Doppler velocity signal. The remaining variation in rotation rate with cell size can be attributed to cells smaller than supergranules extending through shallower layers which have slower rotation rates.

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Improved Kinematics for Brown Dwarfs and Very Low-mass Stars in Cha I and a Discussion of Brown Dwarf Formation

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We present a precise kinematic study of very young brown dwarfs in the Cha I cloud based on radial velocities (RVs) measured with UVES at the VLT. The kinematics of the brown dwarfs in Cha I are compared to the kinematics of T Tauri stars in the same field based on UVES measurements for very low-mass ones and based on RVs from the literature. In comparison with a former paper (Joergens & Guenther 2001), additional UVES spectra have been taken, the reduction of the spectra was improved and a re-study of the literature for RVs of T Tauri stars in Cha I lead to a cleaned and enlarged sample for the T Tauri stars. The result is an improved empirical RV distribution of the brown dwarfs as well as of the T Tauri stars in Cha I. We find that the RVs of the studied nine brown dwarfs and very low-mass stars (M6–M8) in ChaI have a mean value of $15.7\,\mathrm{km\,s^{-1}}$, a dispersion measured in terms of standard deviation of $0.9\,\mathrm{km\,s^{-1}}$, and they cover a total range of $2.6\,\mathrm{km\,s^{-1}}$. The standard deviation is consistent with the dispersion measured in terms of fwhm of $2.1\,\mathrm{km\,s^{-1}}$ by Joergens & Guenther (2001). The studied sample of 25 T Tauri stars (G2–M5) has a mean RV of $14.7\,\mathrm{km\,s^{-1}}$, a dispersion in terms of standard deviation of $1.3\,\mathrm{km\,s^{-1}}$ and in terms of fwhm of $3.0\,\mathrm{km\,s^{-1}}$ and a total range of $4.5\,\mathrm{km\,s^{-1}}$. The RV dispersion of the brown dwarfs is consistent within the errors with that of the T Tauri stars, which is in line with the finding of no mass dependence in some theoretical models of the ejection-scenario for the formation of brown dwarfs. In contrast to current N-body simulations, we do not find a high-velocity tail for the brown dwarfs RVs. We find suggestive hints for different kinematics of binaries compared to predominantly single objects in Cha I, as suggested by some models. The global RV dispersion for Cha I members ($1.24\,\mathrm{km\,s^{-1}}$) is significantly lower than for Taurus members ($2.0\,\mathrm{km\,s^{-1}}$), despite a larger stellar density in Cha I showing that a fundamental increase of velocity dispersion with stellar density of the star forming region is observationally not established. The observed RVs of brown dwarfs in Cha I are less dispersed than predicted by any of the models for the ejection-scenario.

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